Assessment of A Route Choice Model Based on Mental Representations for Traffic Assignment and Route Guidance

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Summary We present a new approach for route choice analysis. It is inspired by the rationale that people break down the complexity of the environment by forming representations of their surrounding space. The proposed framework is based on aggregate elements for the representation of the choice set, denoted as *Mental Representation Items*. This key feature of the framework allows us to reduce the complexity of the model and is more behaviorally realistic than the conventional assumption of *path* alternatives. We have previously presented estimation results using real data to demonstrate the plausibility and validity of the approach[1]. In this work, after briefly the recapitulating the framework, we focus on operational aspects of using the model for traffic assignment and route guidance systems.

Context and motivation Route choice (RC) is one of the key questions in travel demand analysis and the core of traffic assignment. Discrete choice models (DCM) provide a powerful and flexible methodological framework. The use of DCMs for RC analysis involves challenges as compared to standard choice models, e.g. mode choice. The challenges concern the demanding requirements in data collection and processing, the combinatorial nature of the choice set, and the structural correlation due to the physical overlap of paths (Ben-Akiva and Bierlaire (2003)).

Route choice models (RCMs) aim at predicting the route that a given traveler would take to go from the origin of her trip to the destination. A comprehensive review of the route choice modeling problem can be found in Bovy and Stern (1990) and Frejinger (2008). The conventional representation of routes is based on paths that are constructed as sequences of oriented arcs on a connected graph.

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[1]The technical report, *"Revisiting the Route Choice Problem: A Modeling Framework based on Aggregated Choice Sets"*, is upcoming.

In addition to the above mentioned challenges for the modeler, the complexity of the path approach is not consistent with the actual behavior of travelers. The general trend in the literature is to propose more and more complex models to deal with this complexity (Fosgerau et al. (2013); Lai and Bierlaire (2014); Ramos (2015)).

By means of the proposed framework, we are investigating in the opposite direction, i.e. we attempt to simplify the problem. This is accomplished by modeling the strategic decisions of the users, instead of the operational ones, through aggregated choice sets. We have shown that the simplification in the choice set allows us to estimate a model. In the present work, we further discuss the potential of the model for traffic assignment and travel guidance applications.

Definition of the choice model The model is built on the concept *Mental Representation Item* (MRI). An MRI is an item characterizing the mental representation of an itinerary. Each MRI is characterized by a *name*, a *description*, a *geographical span*, and a *representative geocoded point*. A typical example is "the city center". Its description would roughly explain the boundaries of the zone, while the geographical span would describe exactly these boundaries[2]. The representative point may be the most important central intersection in the center.

Following the definition of the MRI, the choice set consists in either one-MRI or sequence-of-MRI alternatives. We start with the simplest case of one MRI per alternative. Each observation of an itinerary, either it comes from interviews or from GPS records, is replaced deterministically by an MRI according to the characterization of the $MRIs$. For the generation of the attributes of the MRI alternatives we follow a deterministic approach that assumes a representative path. The representative path is the fastest path going through the representative point. We use a simple procedure based on a *gateway shortest path* approach, using the representative point of the MRI as the gateway node.

Case study and model estimation In order to test the proposed methodology we use the network of Borlänge in Sweden. The network comprises of 3077 nodes and 7459 unidirectional links. The data comes from GPS records collected from private vehicles in the city of Borlänge, and had been previously processed to obtain map-matched trajectories useful for route choice analysis[3]. Each observation consists in a sequence of links from the origin to the destination node.

After examining the network of Borlänge, it was possible to identify clear choices of one MRI alternatives. A multinomial logit model is estimated with the following aggregated choice set: $\mathcal{C}_n = \{$1: through the city center (CC), 2: clockwise movement around the CC, 3: counter-clockwise movement around the CC, 4: avoid the CC$\}$[4]. The estimation results are consistent, the parameters have the

[2]The definition of the MRI should be specific to the given context and appropriate to keep the model simple and at the same time behaviorally realistic.

[3]We refer to Frejinger and Bierlaire (2007) and Axhausen et al. (2003) for a description of the Borlänge GPS dataset.

[4]The *description* of $MRIs$ in $\mathcal{C}_n$ is common for all individuals N in the sample. What is specific to individual n is

expected signs and they are significant. From this step we obtain the probability of MRI alternative to be chosen, given the list of $MRIs$ in the choice set $\mathcal{C}_n$, denoted as $\mathcal{P}(MRI|\mathcal{C}_n)$.

Application of the model There are two important applications that we want the proposed model to be useful for: (i) traffic assignment, and (ii) design of route guidance systems.

Regarding the former point, we need to transfer from the aggregate alternatives back to paths. We propose to use the *Metropolis-Hastings* sampling of paths that has been introduced by Flötteröd and Bierlaire (2013) to sample paths from the network. The probability of each *path* p to be selected, given the OD and the choice set $\mathcal{C}_n$, is then:

$$\mathcal{P}(p|\mathcal{C}_n) = \sum_{MRI} \mathcal{P}(p|MRI) \cdot \mathcal{P}(MRI|\mathcal{C}_n) \tag{1}$$

where $\mathcal{P}(p|MRI)$ gives the probability of path p to be selected given the MRI. To perform the assignment, we define an indicator function $\delta(p, MRI)$, which is 1 if the sampled path p is consistent with MRI alternative, and 0 otherwise. Finally, $P(MRI|\mathcal{C}_n)$ is the choice model –the parameters of which has been estimated. We validate the model, by applying it in 20% of the OD pairs in the data (the 80% being used for the estimation) using this procedure.

Regarding the latter point, we believe that the proposed approach has potential in the development of route guidance systems, where the provision of information is in an aggregate manner, instead of instructions to follow specific itineraries. A key advantage of the approach in this case, is that the MRI can be used for guidance on variable message signs (VMS) or oral instructions in in-vehicle navigation systems.

Conclusion The proposed framework builds on solid ground of the current state of the art and adds on it by suggesting a new approach that reduces the complexity of the model and brings flexibility to the analyst. The approach tackles with the large size of the choice set and is behaviorally realistic. We further illustrate the plausibility of the approach for traffic assignment. We point out the importance of survey and interview data (i) for the definition of the mental representations, and (ii) to understand how drivers use the information systems, for modelling purposes regarding the former, and for effective design of navigation and travel information systems regarding the latter, based on the MRI approach.

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attributes that the $MRIs$ receive depending on the OD of the trip.

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